WETTING MEASUREMENTS ON POROUS SURFACES UPON BACKPRESSURE APPLICATION

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SUMMARY

Modulation of droplet mobility on surfaces is crucial in numerous technological applications. Here we present an easy to implement methodology in controlling the mobility of water droplets by means of backpressure application. Tuning the backpressure the inherently sticky hydrophobic porous surface may be readily rendered non-sticky, and hence slippery dynamically and reversibly and with low response time. We follow the shape of water droplets upon backpressure.

INTRODUCTION

The importance of studying phenomena related to the mobility of droplets on surfaces has rapidly increased recently due to the numerous pertinent technological applications [1]. The flow in open or closed microfluidics, the collection of rain drops and fog, many chemical processes in droplets, self-cleaning technology, icephobic coatings, membrane contactors, fuel cells [2-4] are only some of the applied areas that call for dynamic, and reversible droplet mobility transitions in order to offer adaptive technical solutions and enhanced performance.

With regard to the droplet mobility, a hydrophobic surface may attain many states from a sticky to multiple slippery states and ultimately the frictionless state. In the first state the droplet pins to the surface and exhibits low mobility, because the liquid fully wets the solid (Wenzel state), as depicted in Figure 1 for the case of a surface with protruding posts.

The concept of our approach is the following. A quiescent droplet on a porous surface partially wets the surface due to the existence of the porosity, in which gas pockets are inherently present [5-11]. Several combinations of porosity morphology and solid surface energy exist in which the intrusion of the liquid in the porous network is not allowable. However, in this energetically stable state, the droplet exhibits low mobility; it is impaled to the surface. With the application of backpressure the volume and the pressure of the gas pockets increase, gradually pushing the liquid out of the porous network. In this pressure-mediated state the droplet exhibits higher mobility and the surface exhibits slippery characteristics. Transitions between these two states are the core of our study. However, further increase of the backpressure accompanied with increased gas flow leverages a droplet take-off and may render the droplet afloat, in which frictionless movement may be realized.

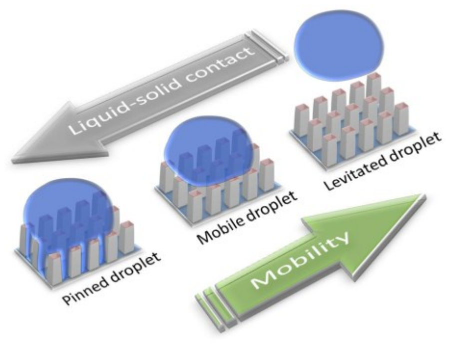

Figure 1. Schematic representation of a droplet exhibiting various wetting states, corresponding to different mobility states of the surface.

SL200KS from Kino was used to measure the contact angle (CA), the CA hysteresis and the tilt angle (α).

RESULTS

In Figure 2 we present the respective experimental data for the porous surface fabricated by extrusion. In this case the pores appear as holes, contrary to the previous case where the particles protrude, as posts. For a virtually horizontal (tilt at 1o) surface (Fig. 5a) the surface exhibits sticky behavior for droplets up to 70 ul. This maximum droplet volume gradually decreases with tilt angle, from 70 ul to 65 ul, 27 ul and 15 ul under the line connecting the experimental data. Significantly lower backpressure values are needed to render the surface slippery, compared to the surface from particles. The effect of the backpressure and the tilt angle is more intense for droplets with volumes bigger than 15 ul.

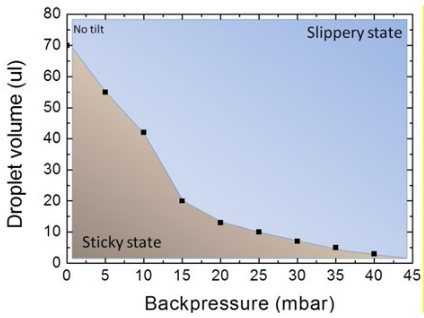

Figure 2. Effect of the backpressure on the mobility of water droplets of various volumes at porous surfaces with holes tilted at 0o.

In Figure 3 we provide for the first time images taken from a contact angle meter, in which the bubble formation and evolution is illustrated and the droplet movement is followed.

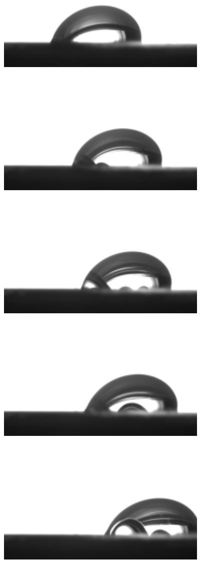

Figure 3. A 60 ul water droplet tilted at 30 deg, is moving upon backpressure application.

CONCLUSIONS

We presented a dynamic with low response time, reversible, and easy-to-implement method to render a porous surface from a sticky to a non-sticky, and hence macroscopically slippery state and back. With the application of backpressure the capillary bridges, which act as hinges hindering the droplet movement, are forced to collapse, thus enabling the downward droplet motion. Droplet movement is recorded by a contact angle meter in situ during actuation. The adequate backpressure to incite the transition from sticky to slippery, is rather low, in the order of some few tens of mbar, thus providing comparative advantages, compared to the state-of-the art pertinent technologies.

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